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QUARTERLY PROGRESS REPORT

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1969

Bellcomm, Inc.

Report No. 69-101-3
Contract NASW-417

Bellcomm, Inc.

QUARTERLY PROGRESS REPORT

April May June

1969

I. M. Ross
President

Bellcomm, Inc.

955 L'Enfant Plaza North, S. W. Washington, D. C. 20024

Report No. 69-101-3
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QUARTERLY PROGRESS REPORT

ABSTRACT

The activities of Bellcomm, Inc., during the quarter ending June 30, 1969 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies.

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Table of Contents

APOLLO/SATURN SYSTEMS ENGINEERING
MISSION PLANNING

Mission Assignments

A revised issue of the Apollo Flight Mission Assignments document was approved in April and subsequently published by NASA. This issue established the detailed objectives for the Apollo 10 and Apollo 11 missions. The Apollo Flight Program Description section was expanded and identified the early lunar landing missions as opportunities to develop the full capability of the Apollo system. Later missions will incorporate advanced systems capabilities as they become available.

Apollo Program Directive No. 51, which deleted lunar landing site No. 1 from consideration for Apollo 11, was prepared for and subsequently released by the Apollo Program Office.

Technical activities related to Apollo 10 included review of Final Launch and Flight Mission Rules, the Mission Operations Report and the Apollo Press Kit. As part of the overall review of Apollo 10 mission options for the Administrator, a background paper was prepared outlining the significant events and decisions that led to the Apollo 10 lunar orbital mission. (1)

Technical activities related to Apollo 11 included review of Preliminary and Final Mission Rules, the Launch Mission Rules, the Flight Plan, the Mission Operations Report, and the Apollo Press Kit.

Lunar Exploration Planning

A study was begun of trajectory profiles for the Exploration Sites tentatively selected at the Site Selection Subgroup meeting of the Group for Lunar Exploration Planning (GLEP) on June 17. Propellant requirements, lunar orbital photographic coverage, and lighting conditions at landing are being examined in this continuing effort.

A study has been completed of visibility improvements by employing a steep descent trajectory rather than the present shallow profile for landings in

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(1) "F" Mission Evolution, Memorandum for File, R. E. Driscoll, May 15, 1969.

the lunar afternoon.(2) Landings in the lunar afternoon are of interest since they can provide a second opportunity to a given landing site in a month and also provide acceptable lunar lighting over a broader range of sun elevations than is permissible with morning landings. When compared to the shallow profile, the results for steep descent showed a decrease in glare due to window contamination by a factor of twenty, resulting in acceptable visibility with the most extreme contamination expected. The study also showed that in the presence of glare, a steep descent almost always has superior visibility compared to the present shallow descent. It concluded, however, that a still better solution to the glare problem for afternoon landings would be to provide an external sunshade on the LM.

Studies were done to characterize the probable benefits of lunar surface mobility, including a ranking of ten selected sites in terms of the relative merit of added mobility for exploration. It was concluded that a roving vehicle could double the useful radius-of-operations, double the number of significant samples obtained, significantly increase the geophysical capability, and remove a large cargo burden from the astronaut. A specific mission profile, keying scientific objectives to specific tasks, was generated for the Marius Hills and presented to the May Management Council Meeting. Lunar flyers were found to be special purpose vehicles which do not appear efficient for horizontal mobility. The small version of the flyer, which has adequate vertical capability, might be effective with pinpoint landings or a roving vehicle for transport.

Continuing site selection activity included the description of geologic characteristics of the twenty-one Set B sites, and participation in the Group for Lunar Exploration Planning (GLEP).(3)

Vehicle Performance

Monthly preparation and delivery of Weight and Performance Reports, as well as presentation of weight and performance status at Apollo Program Office Reviews, continued.

Appropriate changes to the Apollo Program Specification and to spacecraft weight and performance reporting are under study as a result of the MSC report "Revision I to Apollo Spacecraft Weight and Mission Performance Definition".

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(2) This was subsequently reported in Advantage of the Steep Descent for Lunar Surface Visibility During Afternoon Landings, Memorandum for File, R. Troester, July 1, 1969.

(3) Status Report of the GLEP Site Selection Subgroup, Memorandum for File, F. El-Baz, April 9, 1969.

Considerable study and coordination work has been done toward a revised set of weight and performance goals for Lunar Exploration missions. All modules of the Apollo space vehicle are likely to have revised goals when this task is completed.

Mission Analysis

Alternative methods for providing a safe separation distance between the spacecraft and the S-IVB prior to the S-IVB propellant dump were studied.[4] Use of the S-IVB Auxiliary Propulsion System was recommended to provide the separation distance required. This implementation has been studied by MSC and MSFC for use on the H-1 mission.

The coverage that will be achieved with the 210 foot antennas at Parkes and Goldstone for the Apollo 11 July launch opportunities was determined.[5] The data verified that the lunar surface egress and extravehicular activity would be visible for all three launch opportunities over the entire launch window with these two antennas.

The ALSEP mission data handling activities were assessed. Estimates were made of the ALSEP data which would be recorded at the MSFN sites and the subsequent processing load on the MSC computation facilities. The estimates indicated that the ALSEP missions would have minor impact on those facilities.[6]

A study was performed to determine a fuel optimum solution for a rocket in a drag-free central force field.[7] The solution was restricted to powered flights in which the maximum position change is small compared with the distance from the center of the force field, a condition satisfied by most powered maneuvers currently being utilized in space trajectories.

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(4) Spacecraft/Launch Vehicle Evasive Maneuver Considerations, Memorandum for File, D. R. Anselmo, May 22, 1969.

(5) Apollo 11 210 Foot Antenna Visibility for Lunar EVA During the July 1969 Opportunity, Memorandum for File, D. R. Anselmo, May 13, 1969.

(6) ALSEP Data Handling Estimates, Memorandum for File, R. J. Pauly, May 12, 1969.

(7) Optimal Control for a Rocket in a Three-Dimensional Central Force Field, TM-69-2011-2, T. L. Yang, May 29, 1969.

Guidance and Navigation

Manual backup guidance of the launch vehicle into and out of earth orbit was analyzed and results were presented to the Deputy Apollo Program Director. It was approved for use.

Lunar orbit navigation analysis continued.[8,9] A preliminary version of an improved lunar gravity model was furnished to MSC.

The new approach of orbit determination and prediction using time varying osculating orbital elements was applied successfully to Apollo 8 tracking data.[10] Further improvements seem possible with a different set of elements, which are now under study.

The Apollo 11 LM descent trajectory was studied extensively and certain improvements were suggested to MSC.[11] Major topics were discussed with the Apollo Program Director.

Work was continued on the problem of higher accuracy landings on the moon, including methods to improve navigation accuracy at descent ignition and to obtain efficient landing point redesignation capability. To isolate errors due to sources other than MSFN navigation, an error analysis of the LM PGNCS IMU was performed.[12] Dispersions due to these sources will be of the order of 3000 ft or less at the 3-sigma level.

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(8) Forward Propagation Characteristics of Apollo 8 and LL03 Trajectory Solutions, Memorandum for File, J. T. Findlay, M. G. Kelly, April 22, 1969.

(9) Analysis of Lunar Orbiter III Data Using Two Lunar Potential Models, TM-69-2014-3, M. V. Bullock, April 7, 1969.

(10) An Analysis of Apollo 8 Tracking Data Utilizing the Osculating Lunar Elements Program, TM-69-2014-8, M. V. Bullock, A. J. Ferrari, June 30, 1969.

(11) Ideas for Improvement of LM Descent Trajectory, Memorandum for File, G. L. Bush, T. B. Hoekstra, F. LaPiana, June 30, 1969.

(12) Touchdown Position Deviations Due to LM PGNCS IMU Error Sources, Memorandum for File, F. LaPiana, June 24, 1969.

The navigation stars and planets which will be visible in the LM Alignment Optical Telescope were determined for the lunar surface portion of the Apollo 11 Mission.[13] Calculations were made for landing sites 2, 3, and 5 during the July, August and September, 1969, opportunities.

Automatic entry guidance corridors for Apollo 10 and Apollo 11 were studied and found to be satisfactory.[14]

The experimental portion of the Entry Monitor System study was completed. Results applicable to the Apollo 10 mission were presented to MSC, and the remaining results will be presented before Apollo 11.[15] The EMS was found to be compatible with the automatic guidance system for entry speeds up to 37,000 fps. Special EMS procedures were developed for use above that speed and, during the initial portion of the entry manual control, was identified as being preferred over the primary guidance system.

To aid in error analyses, an alternative to pseudo-random numbers for representing error sources was developed and presented at a joint meeting of the Operations Research Society and the American Astronautical Society.[16]

Reports were given to the OMSF Management Council and APO reviews on the status of flight software development, verification and delivery.

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(13) Stars and Planets Visible in the LM AOT During the Lunar Stay Time of the G Mission, Memorandum for File, G. M. Cauwels, T. L. Yang, June 27, 1969.

(14) Guided Entry Corridors for High Velocities, Memorandum for File, S. B. Watson, May 1, 1969.

(15) Entry Monitoring System Study Phase 1, TM-69-2014-7, I. Bogner, G. Duncan, C. H. Eley, III, D. S. Lopez, S. B. Watson, June 26, 1969.

(16) An Alternative to Pseudo-Random Number Generators, TM-69-2014-5, H. J. Bixhorn, April 16, 1969.

APOLLO/SATURN SYSTEMS ENGINEERING PERFORMANCE AND DESIGN REQUIREMENTS

Apollo Program Specification

Revision B of the Apollo Program Specification (SE 005-001-1) was published with an effective date of May 1, 1969. This is the first edition of the specification to be published in an unclassified form.

Communication Systems

The internal routing and processing of the television at MSC for release to the commercial networks was investigated for Apollo 8 and 9 missions.[17] Some changes in system configuration were made for the Apollo 10 mission.

A review of the performance margins of the Apollo 10 color television system showed that good quality television pictures from lunar distance should be received using the 210-foot diameter antenna of the Goldstone, California, station. The picture quality as received through an MSFN station equipped with an 85-foot diameter antenna was predicted to be usable but poor.[18]

The basic television plan and the operation of the sequential color television camera for Apollo 10 were reviewed.[19] Several pre-mission tests of the camera and color system converter were witnessed and a post-mission review of the television system performance was made.

Bellcomm participated with MSC in the extensive testing of the LM VHF transceiver for possible corona effects. Corona effects were noted, but recovery from the failures occurred without permanent damage.

Spacecraft transmitter and earth-based receiver oscillator drifts have been questioned in the past as potential sources of voice distortion in the Apollo VHF voice system. An analysis of the performance of the Apollo VHF voice communications system when the earth-based receiver is detuned indicates that little distortion is generated when the earth-based receiver is detuned

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(17) Description of MSC/News Media Television Interface for Apollo 8 and 9, Memorandum for File, H. Kraus, May 1, 1969.

(18) Anticipated Performance of the Apollo 10-Color Television System, Memorandum for File, R.L. Selden, April 21, 1969.

(19) Apollo 10 Television, Memorandum for File, J.T. Raleigh, April 7, 1969.

as much as 45 percent of the IF bandwidth.[20] The spacecraft and ground equipment appear compatible even when considering the broad VHF voice spectrum and allowable transmitter and receiver oscillator drifts.

Work on realizable near optimum FM demodulators continued with preliminary results showing for some but not all of the Apollo modes about an order of magnitude improvement in performance when compared to the demodulators presently being used for the Apollo FM links.

Launch Systems

A review of the options available to achieve effective LM/SLA prelaunch thermal stabilization at LC-39 concluded that sufficient operational flexibility exists in the system to deal with the problem.[21]

A summary of the Apollo 10 launch area wind constraints was prepared and distributed.[22]

Graphic representations of space vehicle turnaround time and launch window slip as functions of T-time of scrub were prepared for Apollo 10.[23]

Space Vehicle Systems

Effort was continued in several areas relating to analysis of POGO in the Saturn V vehicle.

Spectrum analyses were made of flight data from the Apollo 9 and Apollo 10 missions, and of static firing measurements from the S-II-8 stage, to assist in identification of vibration modes contributing to the POGO phenomenon. The spectrograms of flight data from the S-IVB stage of the Apollo 10 confirmed a distinct structural-propulsion coupling at 19 Hz during the first burn, and showed no indication of structural-propulsion coupling during the 45 Hz oscillation which

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(20) The Effect of Asymmetrical IF Filtering on the Envelope of An AM-PDM Waveform, TM-69-2034-5, W.D. Wynn, June 30, 1969.

(21) LM/SLA Prelaunch Thermal Stabilization at LC-39, Memorandum for File, D.M. Duty, April 14, 1969.

(22) Apollo 10 Wind Constraints, Memorandum for File, W.O. Campbell, May 16, 1969.

(23) Apollo 10 Scrub-Turnaround Curves, Memorandum for File, C.H. Eley, III, May 13, 1969.

occurred during the second burn. These data were presented to the POGO Working Group and to contractor organizations involved in the POGO studies, and will be published in memorandum form in the next quarter.

Time-frequency spectrograms of telemetered data from Apollo vehicles characteristically exhibit spectral components which are generated in the telemetry and data handling systems and are unrelated to the flight data. An analysis was made to identify these spectral components, or artifacts, to aid in interpretation of spectrogram displays.[24]

Work was continued on modeling the structural response of critical components of the vehicle. Advances have been made in the attempt to duplicate the observed flight response of the S-II stage.[25] A program was designed to model the LOX tank as a multiple mass-spring system. This shows reasonable agreement with the static firing data, and holds promise for matching flight data. To assist in resolution of conflicting data on the response of the LOX suction line of the S-II stage, a mathematical model of the MSFC test facility was constructed. Results of this simulation were provided to the POGO Working Group and supported acceptance of the MSFC interpretation of the suction line test data.

Several computer programs were completed to aid in the analysis of large structural systems.[26, 27, 28]

The need for plume deflectors to withstand the increased firing time of the LM-RCS was substantiated for LM-5.[29] For later vehicles use of plume deflectors would permit some reduction in heat shield weight.

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(24) Identification of Artifacts in a Time-Frequency Spectrogram, Memorandum for File, L.A. Ferrara, May 29, 1969.

(25) S-II 27 Degree-of-Freedom Longitudinal Structural Model, Memorandum for File, H.E. Stephens, May 23, 1969.

(26) A Description of the Computer Program "STIFEIG" for Structural Dynamic Analysis, Memorandum for File, S.N. Hou, June 12, 1969.

(27) Dynamic Partitioning Program, Memorandum for File, S. Kaufman, June 6, 1969.

(28) A System Contraction Program (SYCO) For Structural Dynamics, Memorandum for File, S.N. Hou, June 13, 1969.

(29) Remarks on RCS Plume Deflector Being Considered for LM-5 and Subs, Memorandum for File, A.S. Haron, June 6, 1969.

A report on a fire detection method for manned spacecraft was completed.[30] It indicates a system using a mass spectrometer to be the best candidate for rapid and reliable warning.

Summary statements concerning the risks associated with pressure vessel rupture, vehicle explosion on the launch pad, life support system failure, and electrical power system failure were prepared and furnished to the Apollo Program Office for incorporation in the Safety Analysis Report for the Apollo 10 mission.

Lunar Exploration Design Requirements

Information from recently concluded tests was reviewed for applicability to questions of LM habitability for longer lunar staytimes in follow-on exploration missions. Suggestions were made for design of additional tests to advance understanding of the habitability of the extended LM in future missions.[31]

An analysis was made of the sequencing of work and rest periods between lunar orbit insertion and transearth injection (TEI) for the H-1 missions. Three configurations, each using a 2:1 ratio of work to rest were examined. It was concluded that for a 16 hr work/8 hr rest cycle, sleep between the two scheduled surface EVA's and in orbit prior to TEI provides the best possibility of high crew performance. Alternatives are discussed.[32]

Significant factors were summarized concerning locomotion capabilities on the lunar surface as they relate to the current program for development of new suits and backpacks for lunar exploration.[33]

The possibility that motion sickness could occur during pressurized suit operation was recognized, and potential effects on life support systems were discussed with the NASA Space Medicine Directorate. Several preventative

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(30) Fire Detection in Manned Spacecraft By Use of a Mass Spectrometer, TM-69-2031-2, M.V. Drickman, May 20, 1969.

(31) Applicability of "Modified LM Habitability Study" to ELM Habitability, Memorandum for File, P. Benjamin, April 3, 1969.

(32) Analysis of Work/Rest Cycles in the Lunar Environs for the H-1 Mission, Memorandum for File, P. Benjamin, April 23, 1969.

(33) Review of Man/Suit Requirements for Lunar Surface EVA at MSC, Memorandum for File, T.A. Bottomley, Jr., March 31, 1969.

measures were identified and additional options were suggested for future missions requiring extensive pressurized suit operations.

For lunar exploration, the line of sight restriction for voice and data communications is expected to be a significant factor in determining the area that can be explored. Work has begun to investigate the nature of the constraint as a function of lunar landing site and communication system characteristics. As an example, the area which is defined by line of site restrictions at Apollo landing site 2 was mapped.[34]

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(34) Screening of Line of Sight to LM by Craters at Apollo Site 2 - Mission G, Memorandum for File, I.I. Rosenblum, June 30, 1969.

APOLLO/SATURN SYSTEMS ENGINEERING
SCIENTIFIC STUDIES

Lunar Science

The results of a study on the interpretation of the gravity anomaly of lunar mascons in terms of a geological model of the lunar crust and mantle were presented to the American Geophysical Union.[35] The principal conclusions were: (a) the existence of a distinct lunar crust-mantle interface could explain the mascon data, (b) the strength of the lunar mantle must be somewhat greater than the earth's, however not necessarily different in composition, and (c) if the density difference between the lunar crust and the mantle is 0.5 gm/cm^3, the minimum crustal thickness in the Imbrium region is 45 km. In addition, it was tentatively suggested that for craters less than 200 km diameter, the strength of the moon is sufficient to prohibit formation of mascons by mantle upwelling and volcanic filling.

Interpretation of earth-based telescope IR measurements made in 1968 was completed.[36] It was found that infrared emissivity comparison spectra of nine areas on the lunar surface, each 40 km in diameter, indicate that the majority of the lunar surface, including the five prime Apollo sites, has a constant Si:0 ratio so far as present infrared techniques are able to detect. However, an anomaly in the 8μ to 9μ region of the emissivity spectrum of the crater Plato is interpreted as evidence of significantly different Si:0 ratio in the mineral assemblage exposed on that surface.

A theoretical study of the surface distribution of electrostatic potential on the moon was completed.[37, 38] Assuming a steady state potential distribution,

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(35) Mascons as Structural Relief on a Lunar Moho, Paper presented at the American Geophysical Union Meeting, Washington, D.C., April 20-25, 1969, D.U. Wise (NASA), M.T. Yates (Bellcomm).

(36) Differences Between Proposed Apollo Sites - Far Infrared Emissivity Evidence, TR-69-340-2, A.F.H. Goetz (Bellcomm), L.A. Soderblom (California Institute of Technology), June 9, 1969.

(37) Electrostatic Potential Distribution of the Sunlit Lunar Surface, TR-69-710-2, J.L. Blank, W.D. Grobman, April 23, 1969.

(38) Electrostatic Potential Distribution of the Sunlit Lunar Surface, Paper to be published in the "Journal of Geophysical Research," J.L. Blank, W.D. Grobman.

a balance is required between two dominant opposing currents, one resulting from solar wind electron impact on the surface and the other due to photoemission from the surface. Calculations yield a range of 0.6 to 10.2 volts for the potential of the subsolar point, depending on the photoemissive properties of the lunar surface, with an amplitude which decreases monotonically toward the limb. This potential, which is insensitive to the detailed structure of the quiescent solar spectrum, indicates that corrections to the ion energies measured by the ALSEP Suprathermal Ion Detector Experiment (SIDE) will be unimportant at energies above a few electron volts.

A paper cited in the last Quarterly Progress Report had asserted that the interaction of the interplanetary magnetic field with the moon, as measured by a magnetometer at the surface, could determine the interior conductivity structure of the moon.[39] A question was raised that the interplanetary electric field, which had been neglected, was also important. In response it was shown that the electric field interaction is only important in determining the near surface structure and that the deep interior regions of interest respond primarily to the interplanetary magnetic field.[40]

Research was continued on lunar surface processes through the study of Lunar Orbiter photographs. This effort included relating the genetic interpretation of lunar surface deposits near the crater Aristarchus to the general processes of formation of crater-related deposits, and relating the structures near Aristarchus-type craters to the origin of regional stratigraphic units and structural trends surrounding large mare basins.

Presentations relating to lunar surface composition were given at meetings of the American Geophysical Union and the American Astronomical Society.[41, 42]

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(39) Response of the Moon to the Time-Varying Interplanetary Magnetic Field, Paper published in "Journal of Geophysical Research," Volume 74, No. 3, J.L. Blank, W.R. Sill, February 1, 1969.

(40) Reply, Paper to be published in the "Journal of Geophysical Research," J.L. Blank, W.R. Sill.

(41) Compositional Differences Between the Prime Apollo Sites Suggested by Visible and IR Evidence, Paper presented at the American Geophysical Union Meeting, Washington, D.C., April 20-25, 1969, A.F.H. Goetz (Bellcomm), B.C. Murray (California Institute of Technology).

(42) Color Differentiation by Computer Processing, Paper presented at the 129th meeting of the American Astronomical Society, Honolulu, Hawaii, March 30 - April 2, 1969, A.F.H. Goetz (Bellcomm), F.C. Billingsley and J.N. Lindsley (Jet Propulsion Laboratory).

Radiation Studies

Plans for the protection of Apollo astronauts from space radiation have been reviewed.(43) Observations of particle storms occurring on the sun enable several hours warning on the dose exposure for the astronauts. These dose estimates have an initial uncertainty of less than an order of magnitude which decreases as particle data become available during an event. If the projected dose approaches the Maximum Operational Dose, the flight surgeon will be alerted. However, because of the low reliability involved in interpreting the observations, only in relatively severe and well-documented circumstances will protective action be taken.

CSM Science

Several experiment proposals for the CSM science payload were reviewed and recommendations were made to the evaluation committee. Meetings were held to acquaint the principal investigators of the γ-ray Spectrometer and the X-ray Spectrometer with the capabilities of the present Apollo data system and with the capabilities of the suggested augmentation to the present system.

Bellcomm contributed to a technical proposal for a group of experiments involving CSM photography from lunar orbit. The experiments include the photography of areas under earthshine and albedo measurements in permanently shadowed areas near the lunar poles.

An experiment proposal for lunar orbital multispectral photography has been prepared and presented to NASA.(44) This experiment proposal is awaiting approval by the Manned Space Flight Experiments Board.

The selection and use of long focal length lenses for high resolution CM photography has been studied. The study includes lenses from 250 mm to 1250 mm in focal length with image motion compensation provided by the spacecraft control systems.

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(43) Radiation Protection for Apollo Missions, Memorandum for File, R.H. Hilberg, June 25, 1969.

(44) Experiment Proposal for Manned Space Flight: Lunar Multispectral Photography Experiment, S-158, Principal Investigator: A.F.H. Goetz, (Bellcomm), Principal Administrator: R. J. Mackin, Jr. (Jet Propulsion Laboratory), June 2, 1969.

Apollo Surface Experiments

A method was developed to obtain lunar surface temperature measurement by analysis of the thermometer data from the EASEP Dust, Thermal and Radiation Engineering Measurement Package (DTREM).(45) The computer programming for the DTREM data analysis has been initiated. In order to complete the DTREM data acquisition program, background stereo photographs of the emplaced EASEP on Apollo 11 have been requested. The ALSEP Configuration Change Board has approved inclusion of the EASEP DTREM Package on ALSEP on Apollo Missions H-3 and H-4, with possible retrofit to missions H-1 and H-2 if the ALSEP is destacked.

The possible degradation of the Heat Flow experiment which might result from a modified emplacement technique was examined and judged to be not significant.(46) The change in the emplacement technique had been suggested by the Astronaut Office to reduce the complexity of the first lunar drilling operation.

The proposal for a Spent Stage Impact Experiment, described in the last Quarterly Progress Report, was accepted by the chairman of the Lunar Seismology Team. An MSFC study shows that tracking the spent stage during the entire translunar coast could permit adequately precise location of the impact point, and the changes necessary to accomplish this have been recommended. Possible impacting of the spent LM ascent stage is also under study.

Ground Based Apollo Photography

A report on the Bellcomm and Smithsonian Astrophysical Observatory (SAO) coverage of the Apollo 9 mission was completed.(47) Unique pictures of the S-IVB were obtained after the non-nominal last burn. No water dumps were photographed since the photographic windows occurred during portions of the flight when a dump would have interfered with the mission.

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(45) An Engineering Measurement to Obtain the Lunar Surface Thermal Characteristics on EASEP/ALSEP by Analysis of Thermometer Data from the Dust, Thermal and Radiation Engineering Measurement Package (DTREM), Memorandum for File, P.J. Hickson, April 21, 1969.

(46) Modifications to the Apollo Lunar Surface Drill (ALSD), Memorandum for File, P. J. Hickson, April 17, 1969.

(47) Baker-Nunn Photographs Taken During the Apollo 9 Mission, Memorandum for File, A. C. Buffalano, W. D. Grobman, April 4, 1969.

Nominal pointing angles for Apollo 10 were generated for professional and amateur astronomers who were providing optical coverage of the spacecraft and its waste water dump.(48) Real time updates to these pointing angles were calculated for selected observers during the mission. Many photographs of the CSM were obtained, and the results are now being analyzed.

Lunar Surface Lighting

A study was completed relating to lunar exploration under earthshine illumination.(49)

A memorandum was issued which provided data for optimizing exposures of the Hasselblad camera during lunar surface operations.(50)

Data Analysis

Bellcomm participated in editing the Apollo 8 Lunar and Space Science Report. Contributions to the Apollo 10 mission included real time science support during mission operations and participation in the photo debriefing of the crew.(51)

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(48) Photography of the ECS Waste Water Dumps During Apollo 10, Memorandum for File, A. C. Buffalano, May 13, 1969.

(49) Lunar Exploration under Earthshine Illumination, Memorandum for File, V. Hamza, April 4, 1969.

(50) A Chart to Aid in Lunar Surface Camera Operation, Memorandum for File, D. D. Lloyd, April 15, 1969.

(51) Apollo 10 Photo Debriefing, Memorandum for File, F. El-Baz, June 12, 1969.

APOLLO APPLICATIONS SYSTEMS ENGINEERING

Weight Reporting

AAP Weight and Performance Reports for the months of April and May were prepared, summarized for the AAP Director, and issued.

Mission Sequence

An extensive survey was made of computer programs designed to generate astronaut activity and equipment utilization timelines as an aid to the mission planning process.(52) Eighteen timelining models already in use or under development within the aerospace industry were identified. Seven of those models were described in detail and compared from the viewpoint of algorithm structure, input data requirements, output options, manner of assigning task priorities, and capability for contingency analysis. All of the models are organized around three distinct functional areas: data preparation, scheduling, and output. All use one of two basic timeline construction methods: sequential scheduling or window-filling. Significant dissimilarities were noted in the classification of input data and in the criteria for establishing scheduling priorities. Several features that would be desirable in any future scheduling model were pointed out. These included:

a) Modular construction of basic functions to facilitate experimental substitution of different algorithms.

b) Capability to accept externally generated ephemeris data.

c) Initialization with a relatively invariant timeline data base.

The DEEDIX timeline analysis program was modified to produce graphical data on the printer.(53) This form of output permits more rapid and convenient evaluation of amounts of resources consumed during a mission.

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(52) A Survey of Automated Scheduling Models, Memorandum for File, A. B. Baker, April 7, 1969.

(53) BGRAPH - A Plotting Routine for DEEDIX, Memorandum for File, D. P. Nash, April 16, 1969.

The crew timeline currently in use for the AAP-1/AAP-2 mission fails to accomplish seven of the 39 assigned experiments mainly due to assumed scheduling ground rules. A study was undertaken to determine how much improvement is possible if these rules are progressively relaxed.[54] By assuming the UV stellar astronomy and X-ray/UV solar photography experiments could be done by one astronaut, that CM occupancy was not mandatory after workshop activation, and by using the time previously reserved for "mission evaluation", it was found possible to complete all assignments except for 50% completion of the EVA hardware evaluation. The anticipated withdrawal of two Department of Defense experiments will permit 67% completion of this experiment.

Flight Mechanics

Investigations of the guidance, navigation and control performance for the AAP rendezvous missions were continued. A functional description of the LM-A guidance, navigation and control system as configured for the AAP-4 unmanned rendezvous and docking was prepared.[55]

Digital computer simulations were run to determine AAP-1 CSM launch opportunities for rendezvous with the Orbital Workship in an orbit of 35° inclination.[56] The inclusion of an M=16 CSM rendezvous mode (rendezvous 16 orbits after CSM launch) increases the number of launch opportunities over cases where the rendezvous must be accomplished in four orbits or less. It was found that earth oblateness effects cause a small reduction in the launch vehicle performance along northerly launch azimuths compared with launches on comparable southerly azimuths. However, if the maximum southerly launch payload is reduced by 200 lbs to permit a small amount of booster yaw steering, a northerly launch opportunity (as currently baselined) for an M=16 rendezvous mode will exist on 50% of the days. Because of the preponderance of M=16 opportunities, it was suggested that this mode become the baseline for the AAP.

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(54) Increasing the Number of Experiments Planned for Performance During the First AAP Mission, Memorandum for File, D. J. Belz, June 17, 1969.

(55) AAP LM-A GN&C Systems Functions, Memorandum for File, K. E. Martersteck, April 4, 1969.

(56) Launch Opportunities for AAP-1 Rendezvous with OWS at ~35° Inclination, Memorandum for File, I. Hirsch, May 22, 1969.

At the request of the Program Director, a top level AAP software review board is being organized. In conjunction with this activity support was provided to an overall review by MSC of the status of the LM and CM guidance computer software development for AAP.

Work is continuing on the development of a general purpose closed-loop digital navigation and guidance simulator for rendezvous. In addition the Bellcomm Apollo Simulation Program (BCMASP) is being modified to produce open-loop digital rendezvous simulations for mission analysis purposes.

Program Specification

A final draft of the AAP Program Specification covering the wet workshop configuration was delivered to the Program Director on May 15. A marked-up version of this document, reflecting the changes required to cover the Saturn V launched dry workshop concept, was submitted to the Program Director June 17.

Baseline Configuration

Planning and Center coordination was accomplished for the Baseline Configuration Review which was held on May 7-8 at NASA Headquarters. Minutes of this meeting were prepared, approved by the Program Director and distributed.

ATM Film and Camera Stowage

A presentation was given to the AAP Program Director on May 2 outlining problems on stowage, handling and packaging of the ATM film camera and containers in the LM and CSM. The progress achieved by the ATM Camera Coordination Working Group and LM/ATM EVA Working Group was reported and the proposed EVA/Cargo concepts were discussed. Problems which require further study were delineated, and scheduling changes recommended.

Environmental Control System Studies

A study of fluids vented from the AAP Cluster led to a quantitative compilation of all vented fluids and vent properties.[57] A total 5-3/4 tons of liquids, gases, and propulsion exhaust products will be emitted during the lifetime of the Cluster. The immediate effect of fluid discharges will be to create

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(57) A Compilation of Discharged Fluids and Fluid Vent Properties for the AAP Cluster, Memorandum for File, J. J. Sakolosky, June 30, 1969.

an artificial tenuous atmosphere in the vicinity of the Cluster which can degrade the performance of optical experiments. Programming of discharges, when possible, will improve the situation as atmospheric drag will act as a clearing force. A possible long-term effect is a gradual, but cumulative, surface deposition process that would degrade optical surfaces, thermal control coatings, and solar array performance.

The CSM, AM, and OWS Contractors have each proposed a different oxygen partial pressure sensor for use in their module of the AAP Cluster. The operating characteristics and state of development of each were examined.[58] All were found capable of meeting requirements. No cost advantage could be demonstrated for using one type throughout as all are derivatives of previously developed sensors, and integration costs are not reduced because three separate module contractors are involved. Therefore, no recommendation to change sensor types was made. However, it appears feasible to accomplish the OWS atmospheric monitoring task and meet experiment requirements with two, rather than the proposed four, sensors of the mass spectrometer type.

Electrical Power System Studies

An analytical model of the Cluster Electrical Power System was developed, and numerical results were obtained for cases in which the AM solar array and SM fuel cell sources are interconnected for power transfer.[59] It was concluded that the no-load setting of the AM regulators should initially be higher than 30 volts in order to limit the average fuel cell output to 1800 watts over a 56-day mission. Further, two of three fuel cells should be operated when average power requirements exist, with the third used only during extended periods when high loads exist.

The loss of energy incident on solar cells due to quartz coverslides was analyzed.[60] Transmission loss is on the order of 2% and loss due to reflection is about 4% at normal incidence. Reflective loss increases with increasing angle of incidence. A coverslide material with a lower index of refraction will diminish reflective loss.

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(58) A Review of Oxygen Partial Pressure Sensors Proposed for the AAP Cluster, Memorandum for File, J. J. Sakolosky, May 19, 1969.

(59) Analysis of AAP Orbital Assembly Electrical Power Systems, Memorandum for File, L. L. Wang, April 29, 1969.

(60) The Effect of Quartz Coverslides on Radiant Energy Incident on Solar Cells, Memorandum for File, B. W. Moss, April 24, 1969.

Structural Systems

The iterative analytical and experiment procedure used to predict spacecraft structural loads due to ground winds was reviewed.(61) This procedure has been used to establish the maximum ground-wind environment in which it is safe to launch. The required testing and analysis are not yet complete for AAP. The Apollo Program technique of making the launch vs hold decision based on measured loads rather than measured winds was recommended as it avoids the uncertainties (which are usually treated by conservatism) involved in relating wind speeds to loads.

A configuration change which is being made by Apollo in the CM-LM docking interface latch mechanism was noted as a potential problem for AAP because of its effect on the structural dynamics of the cluster.(62) This has been discussed with MSFC and MSC who have initiated a review of the impact on the AAP configuration.

Attitude Control Studies

In connection with the attitude profile under study for the AAP-1/2 and 3A missions that was reported last quarter, a mathematical proof was found which demonstrated that the small amplitude oscillatory motion about the X-POP attitude was unique.(63) Further, an algorithm was obtained for calculating the oscillatory motion from the same spacecraft data used to calculate the gravity-gradient and aerodynamic torques. The significance of this algorithm is that once the oscillatory motion is known, the attitude control system can be designed to track that motion.

Gravity-gradient momentum dump maneuvers based on three different optimization criteria were evaluated for the AAP-3/4 mission.(64) The first

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(61) Relationship Between Spacecraft Structural Capability and Ground Wind Constraints - ML Action Item 157, Memorandum for File, W. W. Hough, April 25, 1969.

(62) Interface Latching Loads, Memorandum for File, R. K. McFarland, June 2, 1969.

(63) Periodic Solutions of the Orbital Assembly Equations of Motion, Memorandum for File, S. C. Chu, April 7, 1969.

(64) CMG Momentum Dump Maneuvers for the AAP-3/AAP-4 Mission, TM-69-1022-4, W. Levidow, May 28, 1969.

criterion, which minimizes the integral of the magnitude of the time-varying maneuver angles, resulted in a maneuver that was difficult to implement. It did suggest, however, a two-attitude dump procedure: a constant dump attitude held from orbital dusk to midnight and a second attitude held from midnight to dawn.

The other two criteria, one proposed by MSFC for implementation for this mission, are based on such a two-attitude scheme. Neither had a distinct advantage; both require maximum maneuver angles of approximately 5° from the solar pointing attitude. The scheme chosen by MSFC for AAP was shown to be a reasonable one.

The problem of executing arbitrary attitude maneuvers with CMG's was investigated in response to the possibility that a Saturn V (Dry) Workshop will require such a capability.[65] The design of the maneuver control law was formulated as a two-part problem: first, to determine the maneuver control torque, and second, to command the CMG gimbal angle rates so as to produce that torque.

The control torque was selected such that the maneuver is executed in minimum time, subject to constraints on the spin angular momentum and torque of the CMG system. A solution to this problem was presented in which the angular acceleration and angular rate about an arbitrary rotation vector are expressed as functions of the rotation angle. From this solution a practical, suboptimal method of maneuver can be developed for implementation on future flight hardware.

The CMG gimbal angle rates required to produce the maneuver control torque were determined so as to minimize their dynamic range.

Thermal Systems Studies

LM-A RCS plume impingement on the AM/MDA radiator during LM-A rendezvous and docking maneuvers was reviewed for the AAP Program Director.[66] It was found that degradation of the thermal performance of the AM/MDA could be expected from contamination of the Z-93 radiator coating; however, the extent of this degradation is unknown and cannot be analyzed with

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(65) Minimum-Time Attitude Maneuvers of Spacecraft with Control Moment Gyroscopes (CMGs), TM-69-1022-7, J. Kranton, June 24, 1969.

(66) Status Report - LM RCS Plume Impingement on the AM/MDA Radiator, Memorandum for File, J. E. Waldo, April 23, 1969.

confidence. AM thermal performance requirements are greatest during EVA/IVA on the AAP-1/2 mission when 45° F water must be provided for the Liquid Cooled Garment. It appears that these requirements could be reduced for AAP-3/4 (when the AM radiator performance might be degraded) since the LM-A will support EVA, and only IVA support for one astronaut will be required from the AM. Test and flight information indicate the current AM radiator coating, Z-93, is more susceptible to contamination from plume effects and ground handling than is another similar zinc-oxide type, S-13G. It was found that currently available test data on plume impingement effects for these thermal coatings are not consistent.

Experiment Support Studies

The pointing requirements of experiments assigned to the AAP-1/2 and AAP-3A missions were reviewed to determine the feasibility of performing them without the addition of special pointing devices. [67] Of the nine experiments examined six were found to have pointing requirements that could be accommodated without additional Workshop Attitude Control System (WACS) propellant. The three experiments with more stringent requirements can be accommodated with the addition of attitude offset controls at the scientific airlock. Target acquisition would be accomplished by small angle maneuvers of the Workshop requiring 5% of the attitude control propellant budget. [68] These results were presented to the Apollo Applications Program Director. [69]

The capability of large, orbiting, manned spacecraft, such as the AAP Orbital Assembly, to support the high accuracy pointing requirements of stellar astronomy is under study. The dynamic distortion of a gimbaled telescope for a worst case astronaut translational maneuver was found to produce a change in pointing direction of from 0.5 to 2.0 seconds of arc. [70]

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(67) Experiment Pointing Requirements for AAP 1-2 and AAP 3A Missions, Memorandum for File, T. C. Tweedie, Jr., April 10, 1969.

(68) 4B Experiment Pointing Capabilities of the WACS, Memorandum for File, J. J. Fearnsides, April 10, 1969.

(69) Compatibility of the 4B Experiment Pointing Requirements with WACS Pointing and Propellant Capabilities, Memorandum for File J. J. Fearnsides, T. C. Tweedie, Jr., April 4, 1969.

(70) Dynamic Distortion of a Gimbaled Telescope, TM-69-1022-3, G. M. Anderson, May 21, 1969.

This distortion exceeds the stability requirement of 0.01 - 0.1 seconds of arc of these telescopes. It was shown that translational decoupling of the gimbal from the spacecraft by means of springs can reduce the dynamic distortion to any desired level, even below 0.01 seconds of arc.

The rigid body motion of a gimbaled telescope with spring decoupling was determined for the gravity-gradient force arising from the orbital motion and for the worst case astronaut translational maneuver. (71) The resulting motion is a function of the natural frequency of the telescope-spring system. This frequency should be placed between the frequency of the orbital motion and the lowest natural frequency of the telescope itself. For a spring-telescope frequency of 0.1 radians/sec the peak to peak spring deflection is 0.5 inches.

Instrumentation and Communications

A review of the instrumentation systems of the AAP Orbital Assembly was completed and presentation was given to the Program Director. The preliminary nature of these proposed systems was stressed while pointing out the need for engineering measurements on first-of-a-kind flight hardware.

An assessment was made of the impact on the Orbital Assembly instrumentation and communications systems if the CSM communications system were powered down during the docked portions of the AAP missions. (72) The study showed that (1) a new audio system would be required in the workshop, including audio centers and VHF or S-Band transmitters; (2) data from experiments located in the CSM and status data on CSM systems would have to be routed to an alternative data system in the Orbital Assembly, as would biomedical data from an astronaut who might be located in the CSM; and, (3) tracking of the Orbital Assembly would have to be accomplished in a skin track mode using the C-Band radars of the MSFN.

A preliminary investigation of the use of Intelsat IV as a relay satellite for demonstrating the continuous relay of voice and limited data during AAP missions was completed and a presentation given to the AAP Program Director.

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(71) On the Translational Motion of a Telescope Elastically Coupled to a Spacecraft Carrier, TM-69-1022-5, J. W. Schindelin, June 12, 1969.

(72) Impact on OA I/C Systems and I/C Capabilities Caused by Deactivating the CSM During Docked Portions of AAP Missions, Memorandum for File, A. G. Weygand, June 26, 1969.

The investigation showed that with a modest terminalon the Orbital Assembly consisting of an eleven foot diameter antenna system and less than 10 watts of transmitter power, a standard Apollo uplink capability (voice and data) and voice and 5.12 kbps on the down-link could be provided through the Intelsat IV Communications Satellite.

Design Reviews

During the quarter, Bellcomm personnel attended and provided technical support for the following program reviews:

- Preliminary Requirements Reviews (PRR) for X-Ray/UV Solar Photography (S020), Mineral Balance (M071), Bioassay of Body Fluids (M073), Foot Controlled Maneuvering Unit (T020), and the Experiment Support System.

- Preliminary Design Reviews (PDR) for Workshop Attitude Control System Propulsion Module, AAP Payload Shroud, and Potato Respiration (S061).

- Critical Design Reviews (CDR) for ATM Solar Array Wing Assemblies, ATM Digital Computer, ATM Polychromator Spectroheliometer (S-055A), and CSM Cryogenic Gas Storage System.

ADVANCED MANNED MISSIONS SYSTEMS ENGINEERING

Program Requirements

In a joint effort with the Office of Manned Space Flight, a draft proposal for a ten-year integrated NASA program was prepared. This included development of versatile earth-orbit and lunar manned capabilities, use of these in a strong science and applications program, and an aggressive automated planetary exploration program opening the option for manned planetary missions in the 1980's. Emphasis was on low cost, re-usability, and common use of hardware, while sustaining both the exploitation and exploration aspects of the agency's long range goals.

At the request of the Directorate of Medical Research and Operations, NASA/MSC, transmitted through the Office of Space Medicine, OMSF, Bellcomm furnished technical and editorial assistance in the compilation of the MSC document, "A Biomedical Program for Extended Space Missions." The document was published in May, 1969, and released in a timely manner to all appropriate organizations and individuals in support of the lunar exploration and space-station/space-base programs. It identified both the observed and anticipated clinical problems attributable to space flight, described past medical approaches to cope with these, established medical positions on the basis of presently available information and defined investigational aims required for space rating man.

Mission Analysis

Astronaut Performance - In flight, an astronaut scans cockpit instruments to identify relevant information, reacts and controls the vehicle. Since there is some evidence that the frequency of the eye movements involved in this scanning is related to fatigue and stress, it has been suggested that measurement of eye movements could serve as a method of anticipating performance degradation during long duration flights.[73] To aid in the investigation of this technique and possibly to provide a means for its implementation, a design concept for a console to evaluate the visual sampling behavior of astronauts was developed. The idea includes the use of pivoting and telescoping arms to obtain a variety of instrument display arrangements and to adjust the distance of the instruments in accordance with the individual's visual field. The same equipment could be used in ground tests and in an orbiting space station.

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(73) Some Design Considerations for a Console to Evaluate the Visual Sampling Behavior of the Astronauts During Long Duration Flights, Memorandum for File, M. A. Robinson, June 12, 1969.

Artificial Gravity - The physical nature of centrifugally obtained artificial gravity was examined from the point of view of a man living inside a rotating environment.[74] It was shown that the artificial gravity of a rotating space station is sufficiently different from the earth's gravity field to require crew training and acclimatization. Dropped or thrown objects and poured liquids follow unusual trajectories; weight increases when moving in the direction of rotation or radially towards the center; manual tasks involving motion have distorted dynamics. It was concluded that artificial gravity may introduce new physiological, habitability and performance problems, and that crew transfer between compartments at different G-levels may require accommodative provisions.

Gulf Stream Drift Mission - The performance of scientific and technical teams of men under conditions of isolation, confinement, and operational stresses analogous to those in long duration space flight is being studied within the Gulf Stream Drift Mission of the Grumman/Piccard PX-15 submersible. NASA is exploring the use of such missions as potential space flight analogs through the attempted extension of laboratory-quality observational techniques into undersea field-study situations. A review was made covering the mission's profile, onboard activities, crew structure, planned and potential return of the NASA related measures in the areas of habitability, maintainability, environmental analysis, microbiology, physiology and behavior.[75]

Project Tektite - An underwater saturation habitat mission, in which four marine scientists lived and worked for 60 days, was completed successfully on April 15, 1969. NASA was involved in this project, along with the Navy and the Department of Interior, because of the applicability of the behavioral, biomedical, and mission planning data from Tektite to future manned space flight missions.

Support was provided to the scientific programs in Tektite. Specifically, the system by which digital data was taken in real time and recorded on punched cards at the Tektite site in the Virgin Islands was developed.[76] A total of some 20,000 cards were used and shipped to Bellcomm at weekly intervals

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(74) Centrifugally Obtained Artificial Gravity, TR-69-730-1, D. B. Hoffman, R. E. McGaughy, April 4, 1969.

(75) Summary of NASA's Participation in the Grumman/Piccard PX-15 ("Ben Franklin") Gulf Stream Drift Mission, Memorandum for File, B. A. Gropper, June 10, 1969.

(76) Tektite Digital Data Logistics and Description of Data Bank at Bellcomm, Memorandum for File, A. J. Cochran, N. Zill, February 18, 1969.

during the mission, where they were sorted and filed on magnetic tape. This data bank provided output to relevant investigators in the form of computer printout, punched cards, or magnetic tape. It also permits easy cross-reference of data from the biomedical, behavioral, and habitat engineering programs. A major portion of the data analysis is presently being done at Bellcomm.

Additionally, work was done in conjunction with psychologists at the Naval Medical Research Institute to develop the behavioral observation system used on Tektite.(77)

Earth Orbit, Lunar and Planetary Missions - Concepts for manned missions in earth orbit and at the moon for the 1970's were examined to determine the potential of the various spacecraft and propulsion modules for possible manned Mars landing missions in the succeeding decade. It was found that a long duration space station module as well as the nuclear and chemical propulsion stages sized for the earth orbital - lunar program could be adapted for planetary use. This would leave the Mars surface landing vehicle, functionally equivalent to a Lunar Module (LM), as the major single development item required for a manned Mars landing. The same shuttle system that has been proposed for earth orbital missions in the 70's could be used for earth orbital assembly and orbital recovery operations at the beginning and end of the manned Mars mission.

In a second study, an integrated long range approach to manned space flight based on common hardware and minimal mission scale was (small payload, small crew) described.(78) A representative set of earth orbital, lunar, and planetary missions were considered to illustrate the potential of a common hardware approach. Advantages and economies include low research and development cost, easier initiation of new programs, low mission hardware cost, reliability, and common support facilities. However, these benefits can probably be realized only if programs in the three mission areas are overlapping or closely spaced.

Nuclear Shuttle - Preliminary estimates indicate that a reusable nuclear vehicle utilized for earth orbit-lunar orbit shuttle operations offers large payload advantages over chemical vehicles of comparative weight despite the effects of radiation from the nuclear rocket.(79) A discussion of the impact of

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(77) Project Tektite Behavior Observer's Handbook, Memorandum for File, N. Zill, April 14, 1969.

(78) An Approach to Manned Space Flight, TM-69-1013-5, D. Macchia, M. H. Skeer, May 13, 1969.

(79) Nuclear Vehicles for Reusable Shuttle Applications, Memorandum for File, D. J. Osias, May 6, 1969.

the artificial radiation levels on schedule time required between shuttle launches, operations, and payloads was presented and estimates of potential advances in the development of high performance nuclear rockets were given.

Orbital ΔV Capability - The on-orbit ΔV capability of a stage and one-half reusable launch vehicle was evaluated for missions in which the vehicle carries less than its maximum payload to orbit.[80] Emphasis was placed on the comparison of ΔV capabilities of vehicles with payload capacities of 10,000 lbs, 25,000 lbs, and 50,000 lbs to low altitude circular orbit. It was found that the larger vehicles have greater on-orbit maneuvering capability.

Configuration Studies

Onboard Checkout - The feasibility of automated onboard checkout for a space station was examined. It was concluded that current aerospace computer technology would allow a considerable amount of limit testing, trend analysis, and diagnosis for up to 2500 test points.[81]

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(80) Orbital ΔV Capability of SOH Launch Vehicle When OFF Loading Payload, Memorandum for File, J. J. Schoch, May 20, 1969.

(81) Onboard Checkout of a Mid-70's Space Station, TM-69-1031-3, J. R. Birkemeier, June 6, 1969.

MISSION OPERATIONS STUDIES

Voice Communications during the major space vehicle tests for Apollo 10 were monitored at KSC. It was found that changes in operational configuration, including use of a VHF constant key mode eliminated some of the problems experienced on Apollo 9, and that a different but similar set of minor problems was encountered. These observations were reviewed with the KSC communications personnel.

During the Apollo 10 mission, the performance of the ground support system was monitored, using the GOSS conference circuit (NET 1), which carries spacecraft-ground voice, and also the MSFN-MCC coordination loop (NET 2). Observations regarding the performance of ground support system were discussed with MSC and GSFC personnel.

Recordings of air-ground transmission during the Apollo 9 mission were analyzed to assist in diagnosis of launch phase voice communication problems reported by the crew. The results were discussed with MSC and GSFC prior to the Apollo 10 mission, and remedial changes in procedures were subsequently instituted.(82) Analysis of the air-ground recordings from the Apollo 10 mission showed no recurrence of the Apollo 9 problems.

An analysis was made of the expected performance margins for transmission of voice and high bit rate (51.2 kbps) telemetry at lunar range, using the CSM omnidirectional antenna to a Deep Space Network station equipped with a 210-foot diameter antenna. (83) This link is a possible contingency mode for operation in event of failure of the high gain antenna system of the CSM. The analysis indicated that usable voice and data could be obtained if the spacecraft attitude could be constrained within a ±30° zone to take advantage of a 5 db on-axis gain in the "omnidirectional antenna."

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(82) Partial Voice Contact Analysis During the Apollo 9 Launch, Memorandum for File, L. A. Ferrara, May 16, 1969.

(83) Performance of Communications Link Between Apollo CSM and DSN 210 Ft. Antenna at Goldstone, Memorandum for File, N. W. Schroeder, May 9, 1969.

In several low capacity space communications channels, such as those from remote sensors on the lunar surface, transmitter oscillator instability is the controlling noise source. A derivation of an optimum detector has been completed which models the phase noise using stepped approximations and assumes a uniform phase distribution.[84] The detector can be readily implemented using a digital computer.

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(84) Optimization of a Very Low Capacity Channel Using a Multi-Tone Frequency Shift Keyed Detector, TM-69-2034-4, L. Schuchman, May 5, 1969.

SPECIAL TASK ENGINEERING STUDIES

Manned Space Flight Experiments Program Studies

Task Order No. 34

Integrated Program Payloads - Candidate experiment payloads for a ten-year NASA integrated program were defined, covering astronomy, physics, life sciences, earth applications and technology. The guidelines were to fulfill major agency objectives by including major portions of programs proposed by the NASA disciplinary planning panels, while utilizing the schedule and systems proposed in the ten-year integrated program worked out with OMSF. Automated and manned programs were integrated wherever feasible.

Mission Effectiveness - A method was given for assessing the effectiveness of a manned space flight mission payload during the planning stage. (85) Effectiveness was taken to be the performance of a given payload compared to the ultimate payload that could be flown on the given mission. The worth of the payload was found as a sum of four factors over all experiments assigned to the mission: 1) priority rating of the experiment discipline among agency goals, 2) priority rating of the experiment in its discipline, 3) rating of suitability to the particular mission, and 4) likelihood of success.

Space Physics - A program for cosmic ray and high energy physics studies in space was defined. (86) A design of a space facility that can perform important measurements on the primary cosmic ray flux in the energy range from a few GeV to 10^6 GeV was presented. It was shown that a small increment in the instrumentation of a cosmic ray space facility, together with the versatility provided by the presence of men rearranging and servicing the hardware, could also provide vital information in the field of high energy physics.

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(85) Mission Effectiveness in Payload Planning, Memorandum for File, F. G. Allen, May 7, 1969.

(86) Cosmic Ray and High Energy Physics Studies in Space, TR-69-103-1, L. Kaufman, April 1, 1969.

Hardware appropriate for space use was described, and various configurations with a large superconducting magnet as the central element were shown. The magnet's capabilities were compared to those of ionization calorimeters.

The implementation of this program is intimately tied to the techniques and needs of accelerator-directed high energy physics, and the involvement of the high energy physics community in this project is desirable.

SPECIAL TASK ENGINEERING STUDIES

Analysis of Haze Effects on Martian Surface Imagery

Task Order No. 35

Work carried out in support of Bellcomm's role as a member of the Photointerpretation Team for the 1971 Mariner Mars orbiter mission progressed in two general areas. A model for the Mars gaseous atmosphere was used to compute the brightness of the atmosphere vs altitude above the planet limb when viewed at zero phase angle.(87) It was determined that the Mariner '71 cameras should be able to measure this brightness profile up to at least 50 kilometers above the surface. If this photography is taken using a single filter, the absolute density profile of the atmosphere can be determined if the composition is known. Photography of the same region of the atmosphere with more than one filter can be used to separate effects of brightness contributions from any non-gaseous part of the atmosphere, such as dust particles.

In the mission analysis area, a set of graphical overlays for a Mercator projection base map was constructed with contours showing viewing and lighting angles. These overlays allow one to determine, for positions on the spacecraft orbit during the nominal 90 day mission, the areas on Mars which can be photographed at a specified set of lighting and viewing conditions. Preliminary sets of these overlays have been made available to other members of the Photointerpretation Team for use in planning their part of the television experiment.

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(87) Preliminary Investigation of the Use of Photographic Measurements of the Atmospheric Brightness of Mars to Study the Atmospheric Structure, Memorandum for File, E. N. Shipley, June 19, 1969.

GENERAL MISSION ENGINEERING STUDIES

Long Range Planning

Support for the NASA Planning System continued. Observers on the Planning Panels participated in the development of disciplinary program alternatives. This work included the preparation of draft material summarizing the recommendations of the Earth Orbit Manned Space Flight Planning Panel, in which alternative flight programs were derived combining the activities of the Earth Orbit and Lunar Exploration programs. Observers on the Planning Steering Group participated in the development of the NASA Long Range Plan and the overall Agency program to be submitted to the President's Space Task Group. A methodology for determining NASA's post-Apollo space program was presented to the Administrator.

Scientific Studies

Asteroids - A paper was published on the distribution of asteroids and the debris resulting from inelastic collisions and subsequent fragmentation of the colliding bodies.(88) The predicted distribution of asteroidal masses agrees well with observation and permits one to extrapolate the distribution of the large observed objects into the distribution of smaller particles.

The influence of inelastic collisions and that of electromagnetic forces on the mass distribution of meteoroids was analyzed.(89) A model distribution was obtained and is in agreement with the latest empirical models used by various workers. It provides theoretical support for these models.

Van Allen Belt Proton and Electron Fluxes - The Bellcomm computer program for estimating the Van Allen Belt proton and electron fluxes was revised to allow incorporation of the latest magnetic field and particle flux

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(88) Collisional Model of Asteroids and their Debris, Paper published in "Journal of Geophysical Research," Volume 74, No. 10, J. S. Dohnanyi, May 15, 1969.

(89) On the Origin and Distribution of Meteoroids, TR-69-105-3-2 J. S. Dohnanyi, April 24, 1969.

models.[90] Major changes in the calculation include an improved description of the earth's magnetic field along with improved routines for calculating the magnetic shell parameter, incorporation of J. I. Vette's models of the trapped particle radiation environment, and calculation of the energy dependence of the particle fluxes. The program is flexible enough to allow inclusion of newer models as they become available, and is applicable to low earth orbit or earth departing missions.

Spacecraft Environment - Computations were made to show that the wake region behind a satellite in earth orbit could be used as an ultrahigh vacuum chamber for experimental purposes.[91] A satellite at 500 kilometers altitude with a suitably outgassed shield whose plane is perpendicular to the flight direction would have a conical region with a pressure of about 10^{-14} millimeters of mercury in the downstream direction.

Astronomy - The possiblity of detecting extra-solar planets and extra-solar life was investigated.[92] The most widely accepted theories of formation of the solar system would predict formation of planetary systems as a natural by-product of stellar formation. Hence, we would expect the existence of many extra-solar planets. If advanced, intelligent life is to exist on a planet, the temperature and mass of the planet must not exceed certain limits, and the planet's "Sun" must have existed stably in excess of a billion years in order for such life to develop and flourish. Various techniques for detecting such planets were considered, and it was concluded that a direct method, probably with an infrared stellar coronagraph, seems most likely to succeed.

A method of obtaining orbital elements of eclipsing binary stars is being developed.[93] The computer model which has been prepared avoids many of

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(90) Bellcomm Orbital Flux Program, TM-69-1011-3, J. S. Ingley, April 1, 1969.

(91) A Satellite Wake Region as an Ultrahigh Vacuum Chamber, Memorandum for File, R. N. Kostoff, May 6, 1969.

(92) The Search for Extra-Solar Planets and Extra-Solar Life, Memorandum for File, D. B. Wood, May 7, 1969.

(93) A Frontal Attack on Eclipsing Binaries, Paper presented at the 129th meeting of the American Astronomical Society, Honolulu, Hawaii, March 30-April 2, 1969, D. B. Wood.

the approximations inherent in existing models. Space-based observations of eclipsing stars will be of such high accuracy that with the application of this model our knowledge of stellar radii, masses, and luminosities may be significantly improved.

A study to determine a method for automatic onboard solar flare detection continued. A computer program to detect flares and extract flare parameters from a digitized image of the sun was completed and documented.(94)

Optical Systems Analysis - The PAGOS computer program, which can analyze the performance of general optical systems, has been adapted to the Univac 1108 and made available in the Bellcomm Applications Program Library.(95) The program computes aberration coefficients, performs a full field ray trace, and produces a spot diagram and Modulation Transfer Function for a system of up to 100 spherical or aspheric optical surfaces. This system can include tilts, displacements, diffraction gratings, vignetting, central obscuration and other phenomena.

Laser Propagation - Two proposals for testing vertical propagation characteristics of the atmosphere at laser frequencies were reviewed.(96) One concept, advanced by Marshall Space Flight Center, centers on an airplane instrument platform; the other, introduced by Goddard Space Flight Center, utilizes balloons. The airplane offers heavier airborne payloads and the possibility of further experiments at minimum recurring costs. The balloons offer more stable paths, complete profile measurements, and longer observation times, but no airborne laser. The time schedules and costs are similar. The concepts are directed toward gaining an understanding of the basic processes of atmospheric propagation and furthering the prospects for successful laser communications between earth and space.

Technological Studies

Nuclear Reactor Systems - A survey of the state-of-the-art of nuclear reactor systems for space electrical power generation revealed that the only

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(94) Computer Program Abstract and Write-up for SFLARE - Solar Flare Detection, Memorandum for File, R. R. Singers, April 25, 1969.

(95) PAGOS-Program for the Analysis of General Optical Systems, Memorandum for File, W. D. Grobman, May 22, 1969.

(96) Laser Propagation through the Atmosphere, Airplane Versus Balloon Testing, Memorandum for File, W. Gale, S. L. Penn, June 2, 1969.

reactor available for manned space flight missions over the next decade is the SNAP-8.[97] Electrical power outputs of 25-70 kilowatts are obtainable; total system weight, including shielding, are in the range of 700-1,000 pounds per kilowatt. Nuclear safety problems involving end-of-life disposal and replacement of the spent reactor present the major operational constraints.

Nuclear stage payload/performance relationships based on linear stage weight scaling laws may be conveniently estimated from a simple nomograph when the stage is started up in a circular orbit. Nomograph equations were derived and illustrated with an example using typical nuclear stage parameters.[98]

On-Orbit Satellite Servicing Studies - A preliminary survey of the potential for satellite servicing was performed.[99] The number and nature of unmanned earth orbiting satellites circa 1980 was estimated in order to assess potential need for and benefit from servicing satellites in orbit. It is expected that approximately 15 satellites per year will require some kind of servicing to extend their useful life.

Studies were undertaken which considered the cost and feasibility of on-orbit satellite servicing from a space station or reusable launch vehicle hangar. Requirements and assumptions necessary to estimate the costs of servicing an astronomy satellite were outlined.[100] Factors influencing servicing hardware, servicing modes, programming issues, astronomy program cost elements, and possible cost models were discussed.

The Infrared Interferometer Spectrometer (IRIS) Sensor flown on the Nimbus Satellite was selected as a subject for detailed analysis of on-orbit

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(97) Nuclear Reactor Systems for Space Electric Power Applications, Memorandum for File, C. P. Witze, June 9, 1969.

(98) Nuclear Stage Performance Estimation, Memorandum for File, M. H. Skeer, April 28, 1969.

(99) Preliminary Survey of the Potential for Satellite Servicing, Memorandum for File, H. B. Bosch, May 22, 1969.

(100) Discussion of Factors Influencing Cost of Servicing Astronomy Satellites, Memorandum for File, D. Macchia, May 21, 1969.

servicing requirements and options. (101) Investigations of the IRIS relevant to on-orbit servicing included instrument/satellite interfaces, on-orbit repair of several existing malfunctions, and sensor updating. Results suggest that, initially, satellite servicing operations would probably involve module level replacement.

Tracking System - A simple and efficient orbiter/balloon communication and tracking system that will enable collection of data on the Venusian atmosphere has been described. (102) The system uses an array antenna on the orbiter operating in a search and an acquisition mode. In the search mode, the beamwidth is wide to allow illumination of several balloons simultaneously; after acquisition, the full array is used narrowing the beam to provide the tracking and data collection function. The collected data is stored on board the orbiter for subsequent transmission to earth. The balloons are equipped with a simple transponder and a data system to provide collection, storage and transmission of data on the Venusian atmosphere.

Data Processing Studies - Studies have been initiated to determine the size in terms of dollars, people, and computers of the current NASA flight operations system. A memorandum was prepared presenting estimates of the Houston Mission Control Center computer requirements during 1969-1973 to support mission control and training for a particular manned space flight planning schedule. (103) An informal presentation of some preliminary results of the study of mission operations was made to the Associate Administrator for Manned Space Flight and the Deputy Associate Administrator (Management).

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(101) Potential On-Orbit Servicing of Nimbus Infared Interferometer Spectrometer (IRIS) Sensors, Memorandum for File, M. H. Skeer, June 5, 1969.

(102) An Orbiter/Balloon Communication and Tracking System for Obtaining Data on the Venusian Atmosphere, TM-69-2034-1, K. H. Schmid, May 22, 1969.

(103) MCC-H Computer Support Requirements for Mission Control and Training, Memorandum for File, R. J. Pauly, May 20, 1969.

Gravity-Measuring Device - A concept for a gravity-measuring device was disclosed.[104] The device detects changes in earth's gravity by measuring variations in the shape of a liquid surface under the action of gravity and surface tension.

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(104) Device for Measuring Changes in the Gravitational Potential on the Earth's Surface, Record of Invention disclosed to NASA, Reportable Item No. 57 under NASW-417, W. J. Martin, June 1969.

ENGINEERING SUPPORT

Computing Facility

During the quarter, a gradual transition was started to convert operation of the UNIVAC 1108 computer from the EXEC II batch operating system to the UNIVAC supplied EXEC 8 multiprogramming operating system. In April, the EXEC 8 system was made available to the major computer users of the UNIVAC 1108 computer for the conversion of all of the most important programs and to increase the data base for evaluation of the EXEC 8 system. That effort was successful and in May and June the EXEC 8 operating system was made available to all users of the computational facilities at Bellcomm. During these two months, about 50% of the work was EXEC II and 50% EXEC 8.

A lack of EXEC 8 system stability remains a major system deficiency. Frequent system 'stops' are occurring due to software errors. An extensive effort is underway to improve the performance of the system.

During the period from April 1 to June 30 NASA Headquarters usage of the UNIVAC 1108 computer was 55.9 hours.

The 1108 computer installation at Bellcomm continues to function as back-up to the 1108 computer complex at MSC during the Apollo missions. Prior to the Apollo 10 mission, the MSC programs were run at Bellcomm to verify the operation of this back-up capability.

LIST OF REPORTS AND MEMORANDA

(List in Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

TITLE	DATE
Response of the Moon to the Time-Varying Interplanetary Magnetic Field, "Journal of Geophysical Research," Vol. 74, No. 3, J. L. Blank, W. R. Sill	February 1, 1969
Tektite Digital Data Logistics and Description of Data Bank at Bellcomm, Memorandum for File, A. J. Cochran, N. Zill	February 18, 1969
A Frontal Attack on Eclipsing Binaries, Paper presented at the 129th meeting of the American Astronomical Society, Honolulu, Hawaii, D. B. Wood	March 30 - April 2, 1969
Color Differentiation by Computer Processing, Paper presented at the 129th meeting of the American Astronomical Society, Honolulu, Hawaii, A. F. H. Goetz (Bellcomm), F. C. Billingsley, J. N. Lindsley (Jet Propulsion Laboratory).	March 30 - April 2, 1969
Review of Man/Suit Requirements for Lunar Surface EVA at MSC, Memorandum for File, T. A. Bottomley	March 31, 1969
Bellcomm Orbital Flux Program, TM-69-1011-3, J. S. Ingley	April 1, 1969
Cosmic Ray and High Energy Physics Studies in Space, TR-69-103-1, L. Kaufman	April 1, 1969

TITLE	DATE
Applicability of the "Modified LM Habitability Study" to ELM Habitability, Memorandum for File, P. Benjamin	April 3, 1969
Baker-Nunn Photographs Taken During the Apollo 9 Mission, Memorandum for File, A. C. Buffalano, W. D. Grobman	April 4, 1969
AAP LM-A GN&C System Functions, Memorandum for File, K. E. Martersteck	April 4, 1969
Centrifugally Obtained Artificial Gravity, TR-69-730-1, D. B. Hoffman, R. E. McGaughy	April 4, 1969
Compatibility of the 4B Experiment Pointing Requirements with WACS Pointing and Propellant Capabilities, Memorandum for File, J. J. Fearnsides, T. C. Tweedie, Jr.	April 4, 1969
Lunar Exploration under Earthshine Illumination, Memorandum for File, V. Hamza	April 4, 1969
A Survey of Automated Scheduling Models, Memorandum for File, A. B. Baker	April 7, 1969
Analysis of Lunar Orbiter III Data Utilizing Two Lunar Potential Models, TM-69-2014-3, M. V. Bullock	April 7, 1969
Apollo 10 Television, Memorandum for File, J. T. Raleigh	April 7, 1969
Periodic Solutions of the Orbital Assembly Equations of Motion, Memorandum for File, S. C. Chu	April 7, 1969
Status Report of the GLEP Site Selection Subgroup, Memorandum for File, F. El-Baz	April 9, 1969
4B Experiment Pointing Capabilities of the WACS, Memorandum for File, J. J. Fearnsides	April 10, 1969

TITLE	DATE
Experiment Pointing Requirements for AAP 1-2 and AAP 3a Missions, Memorandum for File, T. C. Tweedie, Jr.	April 10, 1969
LM/SLA Prelaunch Thermal Stabilization at LC-39, Memorandum for File, D. M. Duty	April 14, 1969
Project Tektite Behavior Observer's Handbook, Memorandum for File, N. Zill	April 14, 1969
A Chart to Aid in Lunar Surface Camera Operation, Memorandum for File, D. D. Lloyd	April 15, 1969
An Alternative to Pseudo-Random Number Generators, TM-69-2014-5, H. J. Bixhorn	April 16, 1969
BGRAPH - A Plotting Routine for DEEDIX, Memorandum for File, D. P. Nash	April 16, 1969
Modifications to the Apollo Lunar Surface Drill (ALSD), Memorandum for File, P. J. Hickson	April 17, 1969
Compositional Differences Between the Prime Apollo Sites Suggested by Visible and IR Evidence, Paper presented at the American Geophysical Union Meeting, Washington, D. C., A. F. H. Goetz (Bellcomm), B. C. Murray (California Institute of Technology)	April 20-25, 1969
Mascons as Structural Relief on a Lunar Moho, Paper presented at the American Geophysical Union Meeting, Washington, D. C., D. U. Wise (NASA), M. T. Yates (Bellcomm)	April 20-25, 1969
Anticipated Performance of the Apollo 10 Color Television System, Memorandum for File, R. L. Selden	April 21, 1969
An Engineering Measurement to Obtain the Lunar Surface Thermal Characteristics on EASEP/ALSEP by Analysis of Thermometer Data from the Dust, Thermal and Radiation Engineering Measurement Package (DTREM), Memorandum for File, P. J. Hickson	April 21, 1969

TITLE	DATE
Forward Propagation Characteristics of Apollo 8 and LL03 Trajectory Solutions, Memorandum for File, J. T. Findlay, M. G. Kelly	April 22, 1969
Analysis of Work/Rest Cycles in the Lunar Environs for the H1 Mission, Memorandum for File, P. Benjamin	April 23, 1969
Electrostatic Potential Distribution of the Sunlit Lunar Surface, TR 69-710-2, J. L. Blank, W. D. Grobman	April 23, 1969
Status Report - LM RCS Plume Impingement on the AM/MDA Radiator, Memorandum for File, J. E. Waldo	April 23, 1969
On the Origin and Distribution of Meteoroids, TR-69-105-3-2, J. S. Dohnanyi	April 24, 1969
The Effect of Quartz Coverslides on Radiant Energy Incident on Solar Cells, Memorandum for File, B. W. Moss	April 24, 1969
Computer Program Abstract and Write-up for SFLARE - Solar Flare Detection, Memorandum for File, R. R. Singers	April 25, 1969
Relationship Between Spacecraft Structural Capability and Ground Wind Constraints - ML Action Item 157, Memorandum for File, W. W. Hough	April 25, 1969
Nuclear Stage Performance Estimation, Memorandum for File, M. H. Skeer	April 28, 1969
Analysis of AAP Orbital Assembly Electrical Power Systems, Memorandum for File, L. L. Wang	April 29, 1969
Description of MSC/News Media Television Interface for Apollo 8 and 9, Memorandum for File, H. Kraus	May 1, 1969

TITLE	DATE
Guided Entry Corridors for High Velocities, Memorandum for File, S. B. Watson	May 1, 1969
Optimization of a Very Low Capacity Channel Using a Multi-Tone Frequency Shift Keyed Detector, TM-69-2034-4, L. Schuchman	May 5, 1969
A Satellite Wake Region as an Ultrahigh Vacuum Chamber, Memorandum for File, R. N. Kostoff	May 6, 1969
Nuclear Vehicles for Reusable Shuttle Applications, Memorandum for File, D. J. Osias	May 6, 1969
Mission Effectiveness in Payload Planning, Memorandum for File, F. G. Allen	May 7, 1969
The Search for Extra-Solar Planets and Extra-Solar Life, Memorandum for File, D. B. Wood	May 7, 1969
Performance of Communications Link Between Apollo CSM and DSN 210 Ft. Antenna at Goldstone, Memorandum for File, N. W. Schroeder	May 9, 1969
ALSEP Data Handling Estimates, Memorandum for File, R. J. Pauly	May 12, 1969
An Approach to Manned Space Flight, TM-69-1013-5, D. Macchia, M. H. Skeer	May 13, 1969
Apollo 10 Scrub-Turnaround Curves, Memorandum for File, C. H. Eley, III	May 13, 1969
Apollo 11 210 Foot Antenna Visibility for Lunar EVA during the July 1969 Opportunity, Memorandum for File, D. R. Anselmo	May 13, 1969
Photography of the ECS Waste Water Dumps During Apollo 10, Memorandum for File, A. C. Buffalano	May 13, 1969
Collisional Model of Asteroids and their Debris, "Journal of Geophysical Research," Volume 74, No. 10, J. S. Dohnanyi	May 15, 1969

TITLE	DATE
"F" Mission Evolution, Memorandum for File, R. E. Driscoll	May 15, 1969
Apollo 10 Wind Constraints, Memorandum for File, W. O. Campbell	May 16, 1969
Partial Voice Contact Analysis during the Apollo 9 Launch, Memorandum for File, L. A. Ferrara	May 16, 1969
A Review of Oxygen Partial Pressure Sensors Proposed for the AAP Cluster, Memorandum for File, J. J. Sakolosky	May 19, 1969
MCC-H Computer Support Requirements for Mission Control and Training, Memorandum for File, R. J. Pauly	May 20, 1969
Orbital ΔV Capability of SOH Launch Vehicle When OFF Loading Payload, Memorandum for File, J. J. Schoch	May 20, 1969
Fire Detection in Manned Spacecraft By Use of a Mass Spectrometer, TM-69-2031-2, M. V. Drickman	May 20, 1969
Discussion of Factors Influencing Cost of Servicing Astronomy Satellites, Memorandum for File, D. Macchia	May 21, 1969
Dynamic Distortion of a Gimbaled Telescope, TM-69-1022-3, G. M. Anderson	May 21, 1969
An Orbiter/Balloon Communication and Tracking System for Obtaining Data on the Venusian Atmosphere, TM-69-2034-1, K. H. Schmid	May 22, 1969
Launch Opportunities for AAP-1 Rendezvous with OWS at $\sim 35°$ Inclination, Memorandum for File, I. Hirsch	May 22, 1969
PAGOS-Program for the Analysis of General Optical Systems, Memorandum for File, W. D. Grobman	May 22, 1969

TITLE	DATE
Preliminary Survey of the Potential for Satellite Servicing, Memorandum for File, H. B. Bosch	May 22, 1969
Spacecraft/Launch Vehicle Evasive Maneuver Considerations, Memorandum for File, D. R. Anselmo	May 22, 1969
S-II 27 Degree-of-Freedom Longitudinal Structural Model, Memorandum for File, H. E. Stephens	May 23, 1969
CMG Momentum Dump Maneuvers for the AAP-3/AAP-4 Mission, TM-69-1022-4, W. Levidow	May 28, 1969
Identification of Artifacts in a Time-Frequency Spectrogram, Memorandum for File, L. A. Ferrara	May 29, 1969
Optimal Control for a Rocket in a Three-Dimensional Central Force Field, TM-69-2011-2, T. L. Yang	May 29, 1969
Device for Measuring Changes in the Gravitational Potential on the Earth's Surface, Record of Invention disclosed to NASA, Reportable Item No. 57 under NASW 417, W. J. Martin	June 1969
Interface Latching Loads, Memorandum for File, R. K. McFarland	June 2, 1969
Laser Propagation through the Atmosphere, Airplane versus Balloon Testing, Memorandum for File, W. Gale, S. L. Penn	June 2, 1969
Potential On-Orbit Servicing of Nimbus Interferometer Spectrometer (IRIS) Sensor, Memorandum for File, M. H. Skeer	June 5, 1969
Dynamic Partitioning Program, Memorandum for File, S. Kaufman	June 6, 1969
Onboard Checkout of a Mid-70's Space Station, TM-69-1031-3, J. R. Birkemeier	June 6, 1969

TITLE	DATE
Remarks on RCS Plume Deflector Being Considered for LM-5 and Subs, Memorandum for File, A. S. Haron	June 6, 1969
Nuclear Reactor Systems for Space Electric Power Applications, Memorandum for File, C. P. Witze	June 9, 1969
Differences Between Proposed Apollo Sites - Far Infrared Emissivity Evidence, TR-69-340-2, A. F. H. Goetz (Bellcomm), L. A. Soderblom (California Institute of Technology)	June 9, 1969
Summary of NASA's Participation in the Grumman/Piccard PX-15 ("Ben Franklin") Gulf Stream Drift Mission, Memorandum for File, B. A. Gropper	June 10, 1969
A Description of the Computer Program "STIFEIG" For Structural Dynamic Analysis, Memorandum for File, S. N. Hou	June 12, 1969
Apollo 10 Photo Debriefing, Memorandum for File, F. El-Baz	June 12, 1969
On the Translational Motion of a Telescope Elastically Coupled to a Spacecraft Carrier, TM-69-1022-5, J. W. Schindelin	June 12, 1969
Some Design Considerations for a Console to Evaluate the Visual Sampling Behavior of the Astronauts During Long Duration Flights, Memorandum for File, M. A. Robinson	June 12, 1969
A System Contraction Program (SYCO) for Structural Dynamics, Memorandum for File, S. N. Hou	June 13, 1969
Increasing the Number of Experiments Planned for Performance During the First AAP Mission, Memorandum for File, D. J. Belz	June 17, 1969

TITLE	DATE
Preliminary Investigation of the Use of Photographic Measurements of the Atmospheric Brightness of Mars to Study the Atmospheric Structure, Memorandum for File, E. N. Shipley	June 19, 1969
Minimum-Time Attitude Maneuvers of Spacecraft with Control Moment Gyroscopes (CMGs), TM-69-1022-7, J. Kranton	June 24, 1969
Touchdown Position Deviations Due to LM PGNCS IMU Error Sources, Memorandum for File, F. LaPiana	June 24, 1969
Radiation Protection for Apollo Missions, Memorandum for File, R. H. Hilberg	June 25, 1969
Entry Monitoring System Study Phase 1, TM-69-2014-7, I. Bogner, G. Duncan, C. H. Eley, III, D. S. Lopez, S. B. Watson	June 26, 1969
Impact on OA I/C Systems and I/C Capabilities Caused by Deactivating the CSM During Docked Portions of AAP Missions, Memorandum for File, A. G. Weygand	June 26, 1969
Stars and Planets Visible in the LM AOT During the Lunar Stay Time of the G Mission, Memorandum for File, T. L. Yang, G. M. Cauwels	June 27, 1969
A Compilation of Discharged Fluids and Fluid Vent Properties for the AAP Cluster, Memorandum for File, J. J. Sakolosky	June 30, 1969
An Analysis of Apollo 8 Tracking Data Utilizing the Osculating Lunar Elements Program, TM-69-2014-8, M. V. Bullock, A. J. Ferrari	June 30, 1969
Ideas for Improvement of LM Descent Trajectory, Memorandum for File, G. L. Bush, T. B. Hoekstra, F. LaPiana	June 30, 1969

TITLE	DATE
Screening of Line of Sight to LM by Craters at Apollo Site 2 - Mission G, Memorandum for File, I. I. Rosenblum	June 30, 1969
The Effect of Asymmetrical IF Filtering on the Envelope of An AM-PDM Waveform, TM-69-2034-5, W. D. Wynn	June 30, 1969
Advantage of the Steep Descent for Lunar Surface Visibility During Afternoon Landings, Memorandum for File, R. Troester	July 1, 1969
Experiment Proposal for Manned Space Flight: Lunar Multispectral Photography Experiment S-158, Principal Investigator: A. F. H. Goetz (Bellcomm), Principal Administrator: R. J. Mackin, Jr. (Jet Propulsion Laboratory)	July 2, 1969
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Reply, Paper to be published in the "Journal of Geophysical Research," J. L. Blank, W. R. Sill	To be published